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MODELLING OF INFILTRATION RATE OF RED SOIL UNDER DIFFERENT LAND USE CONDITIONS

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ABSTRACT

Modeling of infiltration studies of Red soils under different land use conditions was carried at “FRUIT RESEARCH STATION”at Sangareddy, Medak District of a latitude of 17.6294° N and longitude of 78.0917° E. Infiltration is a dynamic process, variable in time and space and plays a vital role in the replenishment of soil water which is responsible for the growth and development of crops. It plays an important role in design of farm irrigation, scheduling of irrigation etc. Infiltration rate was estimated in red soil with double ring infiltrometer for the four soil conditions namely 1).Ploughed condition 2).Unploughed condition 3). Compacted soil and 4) Continuous fallow land. Three empirical models namely 1) Kostiakov model 2) Modified Kostiakov model and 3) Horton’s model were selected to develop constants and coefficients in order to predict the infiltration rate. Using the estimated coefficients and constants, the three infiltration equations for different soil conditions were formulated. For the ploughed land, it was found that, the Horton’s model with correlation coefficient as 0.99 fitted well followed by Modified Kostiakov and Kostiakov. In unploughed land, the both Modified Kostiakov and Horton’s models gives the best fit with correlation coefficient of 0.99 followed by Kostiakov model. In Compact land, it was found that, the Horton’s model gives the best fit with correlation coefficient as 0.99 followed by Modified Kostiakov and Kostiakov model. In Continuous fallow land, it was found that, the Horton’s model gives the best fit with correlation coefficient as 0.99 followed by Modified Kostiakov and Kostiakov model. Finally it was concluded that Horton’s model can be effectively used for the soils of this region for different land use patterns.

KEYWORDS: Infiltration, Infiltration Rate, Double Ring Infiltrometer

INTRODUCTION

Infiltration is the downward entry of water into the soil. The velocity with which water enters the soil is infiltration rate. Infiltration is one of the major components of the hydrology cycle. Water that falls as precipitation may run over land eventually reaching streams, lakes, rivers and oceans or infiltrate through the soil surface into the soil profile. Water that runs off over land causes erosion, flooding and degradation of water quality. Infiltration, on the other hand, constitutes the sole source of water to sustain the growth of vegetation, is filtered by the soil which removes many contaminants through physical, chemical and biological processes, and replenishes the ground water supply to wells, springs and streams (Rawals*et al*, 1993). The ability to quantify infiltration is of great importance in watershed management. Prediction of flooding, erosion and pollutant transport depends on the rate of runoff which is directly affected by the rate of infiltration.

In the present study the constant infiltration rates of red soil under different soil conditions were calculated by double ring infiltrometer method, and compared with calculated values from Kostiakov, Modified Kostiakov and Horton's models (1939 and 1940) Assessment of the suitability of different models for estimation of infiltration rate of red soil under particular soil condition was carried out with correlation coefficient.Jejurkar, C.L. and M.P. Rajukar(2012) concluded that winter season in Grapes land Horton equation shown much variation, but Kostiakov equation and Modified Kostiakov equations were almost coinciding with measured cumulative infiltration. In summer season Grapes land Horton equation shown much variation but Kostiakov equation and modified Kostiakov equation shown little variation with measured cumulative infiltration. G.E., Osuji*et al* (2010) revealed that different land use practice affect the infiltration rate of the soil. This is due to their effect on intrinsic properties of the soil. The very low correlation coefficient obtained with sand and clay percentage reveals that texture does not account for any significant variation in the infiltration rates under these conditions. Also it was found that different land use practices have no significant effect on the soil texture.

MATERIALS AND METHODS

Study Area

Fruit research station in Medak District of Telangana state was selected for the study, which was having Latitude of 17.6294° N and longitude of 78.0917° E. Four soil conditions under red soil were selected for infiltration rate measurement.

Experimental Setup

Double ring infiltrometer method was used for measurement of infiltration rates at all the soil conditions. In this two concentric rings (Plate.1) were used with 30 cm deep, and diameter of 30 cm for inner ring and 60 cm for outer ring. The rings were driven 15 cm deep into soil by using falling weight type hammer striking on a wooden plank placed on top of ring uniformly without or undue disturbance to soil surface.

Plate 1: Double Ring Infiltrometer

Water was poured into the rings to maintain depth of 10 to 15 cm and the quantity of water was added to maintain this depth at regular time interval of 5, 10, 20, 30 min. upto getting a constant infiltration depth. The infiltration depth in inner ring is determined with the help of point gauge and stop watch etc. To avoid the seepage of water from inner ring to outer and vice-versa, the water levels in both the cylinders are kept approximately same. The readings have been taken at each experimental setup. The infiltration rate is calculated by the following formula

$$\text{Infiltration rate (cm/h)} = \frac{Initial\ water\ depth\ (cm) - Final\ water\ depth (cm)}{Time\ required, h}$$

Infiltration Models

The following infiltration models were assessed for finding best fitting model to observed field infiltration rate data.

Kostiakov Equation

Kostiakov (1932) and independently Lewis (1938) proposed a simple empirical infiltration equation based on curve fitting from field data. It relates infiltration to time as a power function:

$F = a\,t^{b}$

Where

F_p= Cumulative infiltration capacity [cm/h],

t= Time after infiltration starts [h], and

a and b are constants that depend on the soil and initial conditions.

The parameters, *a* &b must be evaluated from measured infiltration data.a& b values ranges between 0 to 1.

Modified Kostiakov Equation

$$f = at^{b} + c$$

Where

f = cumulative infiltration at any time t [cm/hr].

t = is time in min.

a, b and c are constants whose values depend on soil type (0 to 1)

Horton's Equation

The Horton model of infiltration (Horton, 1939 and 1940) is one of the best-known models in hydrology. Horton recognized that infiltration capacity (I) decreased with time until it approached a minimum constant rate (f_c). Horton's perceptual model of infiltration processes was far more sophisticated and complete than normally presented in hydrological texts.

$$I = f_c + (f_o - f_c)\,e^{-k\,t}$$

Where

I = Infiltration capacity or potential infiltration rate [cm/h],

f_c = Final constant infiltration rate [cm/h],

f_o = Initial infiltration capacity [cm/h],

k = Horton's decay coefficient which depends upon soil characteristics and vegetation cover

t = Time after start of infiltration (h).

RESULTS AND DISCUSSIONS

The measured infiltration rates and simulated infiltrations of red soil under different soil conditionsare given a in tables 1, 2, 3, 4 and 5.

Table 1: Comparison between Observed and Simulated Infiltration Rates by Different Infiltration Models for Ploughed Soil

Time	Observed Infiltration Rate, cm/h	Infiltration Rate Modified Kostiakov Model, cm/h	Infiltration Rate Horton's Model, cm/h	Infiltration Rate Kostiakov, cm/h
0.08	24	25.2	23.68	24.48
0.167	10.8	9.6	10.56	11.16
0.25	10.8	8.4	10.45	8.76
0.33	7.2	6	6.97	7.44
0.416	7.2	7.2	6.92	6.66
0.5	6	4.8	5.77	6
0.58	4.8	6	4.67	5.64
0.67	4.8	4.8	4.65	5.28
0.75	4.8	4.8	4.63	4.92
0.833	3.6	4.68	3.6	4.68
0.916	3.6	3.72	3.6	4.56
1	3.6	4.68	3.6	4.2
Correlation Coefficient		0.9596	0.9990	0.9787

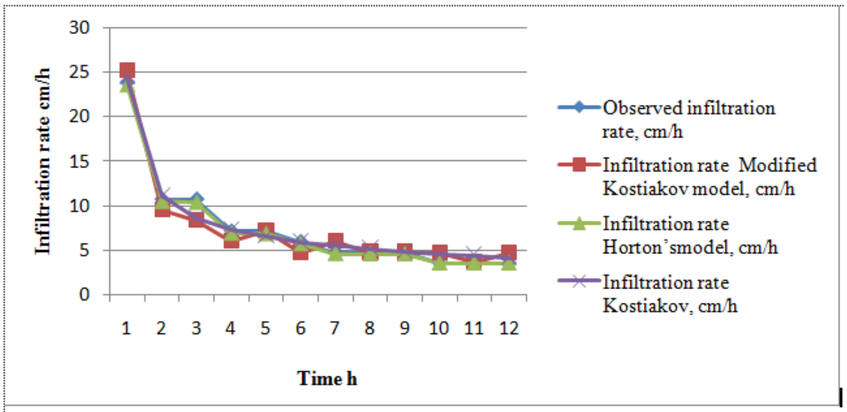

Figure 1: Observed and Predicted Infiltration Rates of Ploughed Soil under Different Soil Conditions

Table 2: Comparison between Observed and Simulated Infiltration Rates by Different Infiltration Models for Unploughed Soil

Time	Observed Infiltration Rate, cm/h	Infiltration Rate Modified Kostiakov Model, cm/h	Infiltration Rate Horton's Model, cm/h	Infiltration Rate Kostiakov, cm/h
0.08	9.6	9.6	9.54	9.36
0.167	4.8	4.8	4.76	4.56
0.25	3.6	3.6	3.57	3.6
0.33	2.4	2.4	2.4	3.24
0.416	2.4	2.4	2.4	2.76

Table 2: Contd.,				
0.5	2.4	2.4	2.4	2.64
0.58	2.4	2.4	2.4	2.4
0.67	2.4	2.4	2.4	2.4
0.75	2.4	2.4	2.4	2.16
0.83	2.4	2.4	2.4	2.04
0.916	2.4	2.4	2.4	1.92
1	2.4	2.4	2.4	1.92
1.08	2.4	2.4	2.4	1.92
1.16	2.4	2.4	2.4	1.68
1.25	2.4	2.4	2.4	1.8
Correlation Coefficient		0.9999	0.9990	0.9548

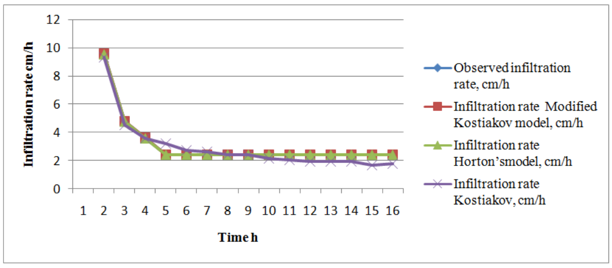

Figure 2: Observed and Predicted Infiltration Rates of Unploughed Soil under Different Soil Conditions

Table 3: Comparison between Observed and Simulated Infiltration Rates by Different Infiltration Models for Compact Soil

Time	Observed Infiltration Rate, cm/h	Infiltration Rate Modified Kostiakov Model, cm/h	Infiltration rate Horton's Model, cm/h	Infiltration Rate Kostiakov, cm/h
0.08	2.4	2.64	2.38	1.68
0.016	1.8	1.92	1.78	1.56
0.25	1.8	1.56	1.76	1.44
0.33	1.2	1.56	1.2	1.32
0.41	1.2	1.56	1.2	1.32
0.5	1.2	1.32	1.2	1.2
0.58	1.2	1.32	1.2	1.2
0.66	1.2	1.44	1.2	1.2
0.75	1.2	1.32	1.2	1.2
0.833	1.2	1.2	1.2	1.08
0.916	1.2	1.2	1.2	1.08
1	1.2	1.32	1.2	1.08
1.083	1.2	1.08	1.2	1.08
1.16	1.2	1.2	1.2	1.08
1.25	1.2	1.2	1.2	1.08
1.33	1.2	1.2	1.2	0.96
1.416	1.2	1.08	1.2	0.96
1.5	1.2	1.08	1.2	0.96
1.583	1.2	1.08	1.2	0.96
1.667	1.2	1.2	1.2	0.96
1.75	1.2	1.08	1.2	0.96
1.83	1.2	1.08	1.2	0.96
1.916	1.2	0.96	1.2	0.96
Correlation Coefficient		0.7823	0.9980	0.8117

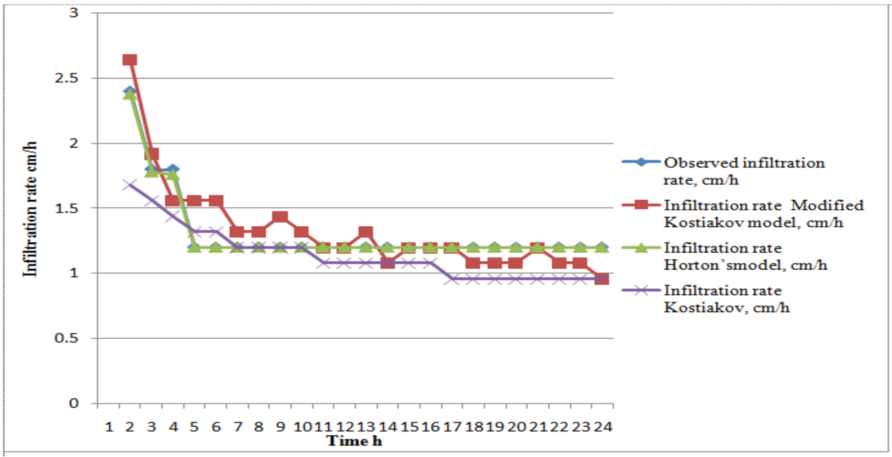

Figure 3: Observed and Predicted Infiltration Rates of Compact Soil under Different Soil Conditions

Table 4: Comparison between Observed and Simulated Infiltration Rates by Different Infiltration Models for Continuous Fallow Land

Time	Observed Infiltration Rate, cm/h	Infiltration Rate Modified Kostiakov Model, cm/h	Infiltration Rate Horton's Model, cm/h	Infiltration Rate Kostiakov, cm/h
0.08	84	4.351	83.3	90.48
0.167	36	8.177	35.73	24.12
0.25	18	11.87	17.64	16.92
0.33	13.2	15.51	12.89	13.44
0.416	9.6	19.08	9.38	11.4
0.5	7.2	22.61	7.07	10.08
0.58	4.8	26.11	4.8	8.88
0.67	4.8	29.58	4.8	8.16
0.75	4.8	33.03	4.8	7.32
Correlation Coefficient		0.7823	0.9900	0.9605

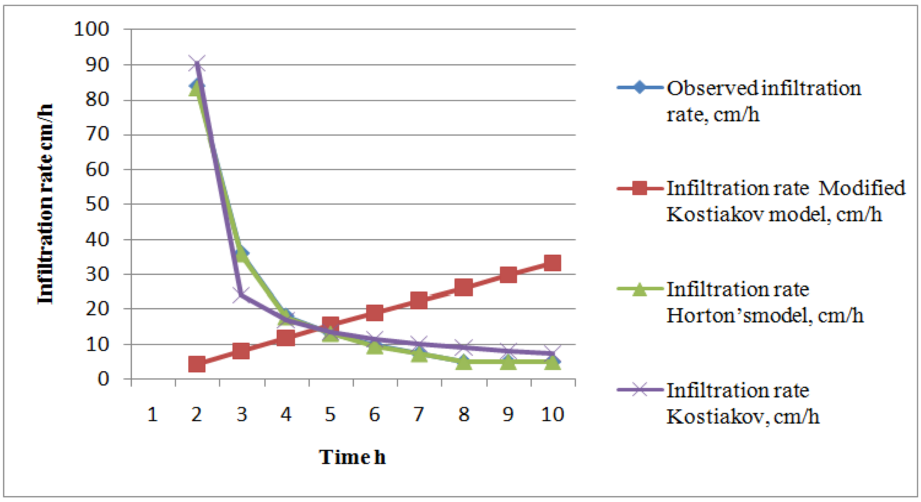

Figure 4: Observed and Predicted Infiltration Rates of Continuous Fallow Land under Different Soil Conditions

Table 5: The Values of Different Parameters of Infiltration Models for Red Soil under Different Soil Conditions

Soil Condition	Kostiakov Model		Modified Koastiakov Model			Horton's Model
	a	b	a	b	c	k
Ploughed condition	0.0544	0.7983	0.69	0.38	0.57	0.196
Unploughed condition	0.3096	0.5748	0.23	0.22	0.64	0.094
Compact land	0.0548	0.7957	0.056	0.018	0.801	0.245
Continuous fallow land	0.2280	0.3396	0.910	0.190	0.940	0.1103

From the results it was found that the values of parameters of infiltration models vary from soil condition. Also the correlation coefficients were different for different soil conditions. From analysis it was found that for all type of soil conditions Horton’s model was best fitting with high degree of correlation coefficient, except for unploughed conditions.

Also the graphs of measured infiltration rate and calculated infiltration rate by different models against time were drawn for red soil under different soil conditions and it was observed that initially infiltration rates were higher and decreased with time upto constant infiltration rate.

SUMMARY AND CONCLUSIONS

From the research work the following conclusions are drawn:

- Constant infiltration rate of ploughed, unploughed compact and continuous fallow land use pattern of red soil was 3.6 cm/h, 2.4 cm/h, 1.2 cm/h and 4.8 cm/h respectively.
- Infiltration rate gets affected by soil condition
- The cultivated land has shown considerable impact on higher infiltration rate was noticed due to increase in porosity.
- Average infiltration rate decreases as time increases which is an indication of higher degree of saturation of soil as time progresses.
- The coefficients and constants of infiltration models vary for different soil conditions. Which clearly shows that infiltration rate is different in different soil conditions.
- Horton’s model can be effectively used for predicting infiltration rate in ploughed, compact and continuous fallow land in red soils.
- Modified Kostiakov model can be used to predict infiltration rate accurately in unploughed soil.
- Based on the predicted infiltration rate runoff can be assessed which in turn help in finalising the irrigation scheduling for the crops grown. The best method of irrigation and frequency of machine operations during the cropping season can also be worked out.

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